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(12) UK Patent Application (19) GB (11) 2 223 129 (13) A

(43) Date of A publication 28.03.1990

(21) Application No 8822609.7

(22) Date of filing 27.09.1988

(51) INT CL[4]
H01Q 3/26

(52) UK CL (Edition J)
H1Q QFJ

(56) Documents cited
None

(58) Field of search
UK CL (Edition J) H1Q QFA QFC QFD QFF QFH QFJ
INT CL[4] H01Q

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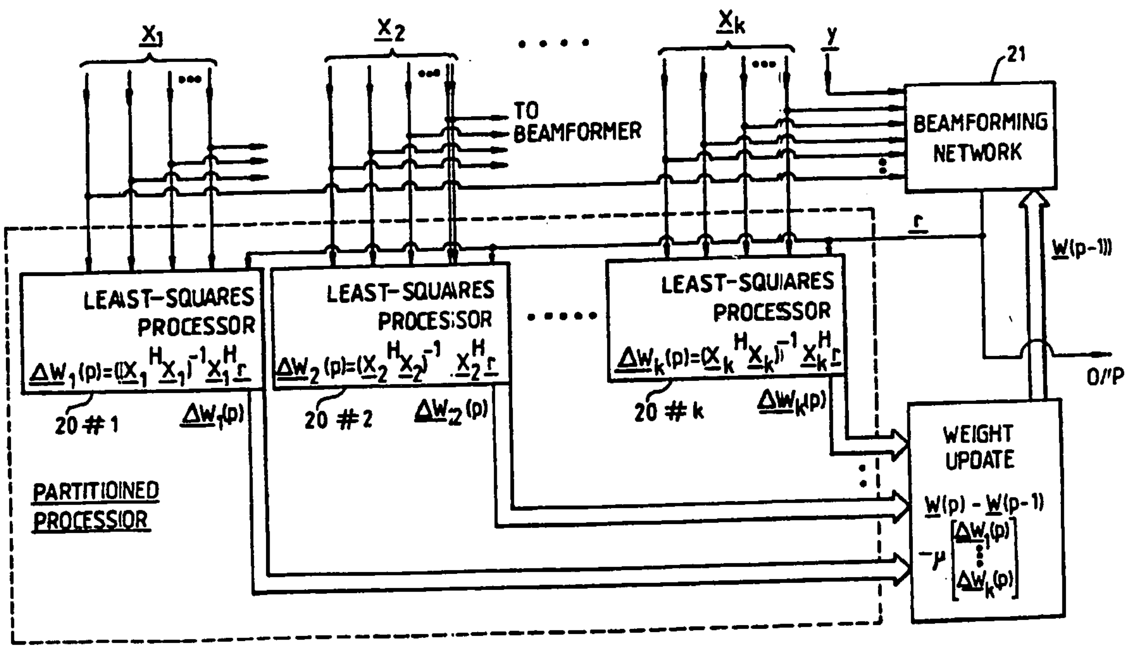
(54) **Processor for adaptive array antenna**

(57) An accelerated convergence adaptive antenna arrangement wherein the auxiliary signal inputs to the beam pattern controller are divided into groups $\underline{x}_1$ - $\underline{x}_k$, the controller being provided with an equivalent number of processors 20#1 - 20#k, each group of auxiliary signals being processed separately in conjunction with the output of beam former 21 by a respective processor the operation of which is to compute a weight correction vector by a least squares process or an approximation thereof, all the groups being processed in parallel to form a set of weight correction vectors $\underline{\Delta W}_1$ (p) - $\underline{\Delta W}_k$ (p) which are used to update the weight vector $\underline{W}$ (p-1) applied to the beam forming network to which all the auxiliary signals and primary channel signal are applied.

Fig.2.



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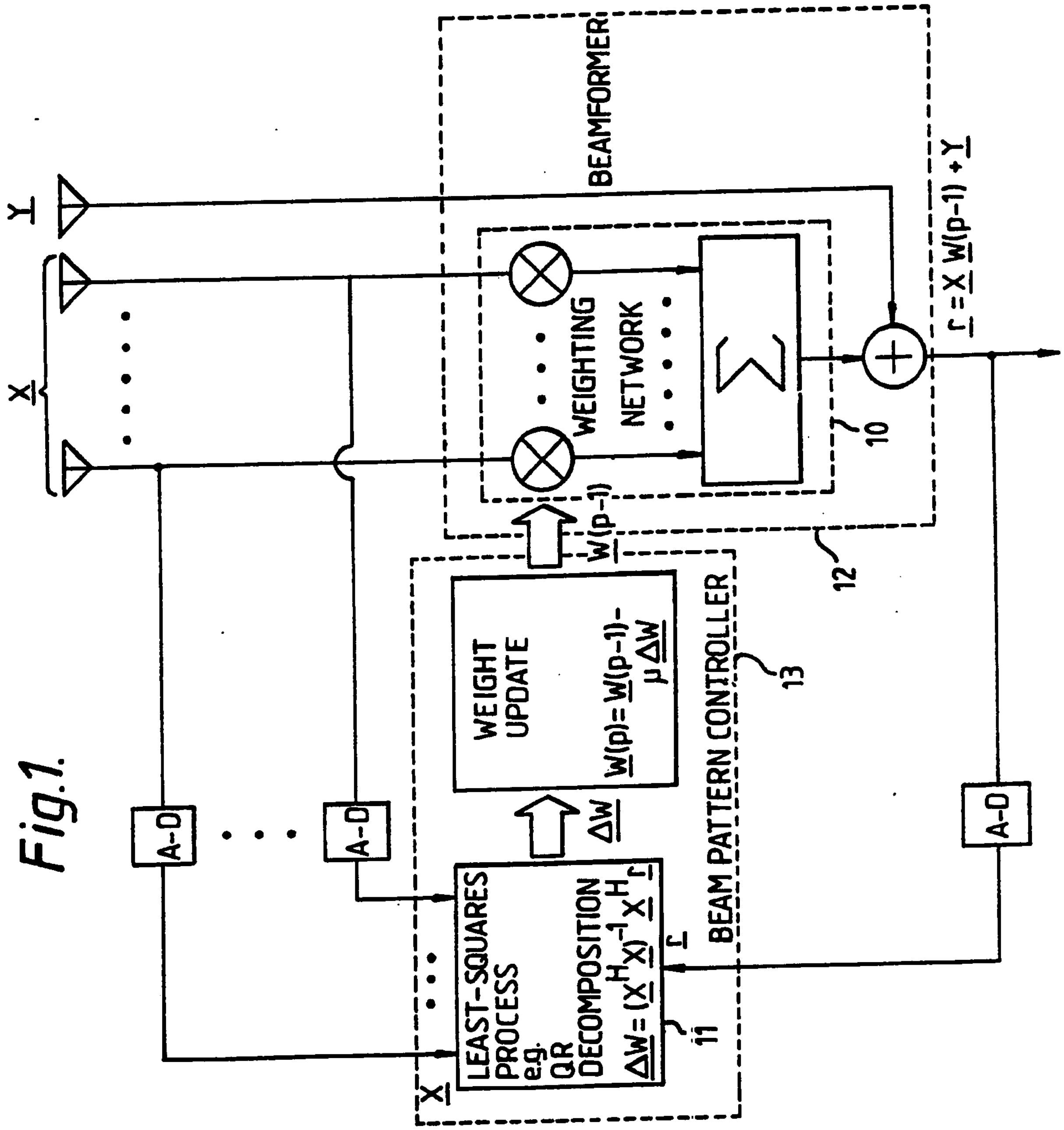
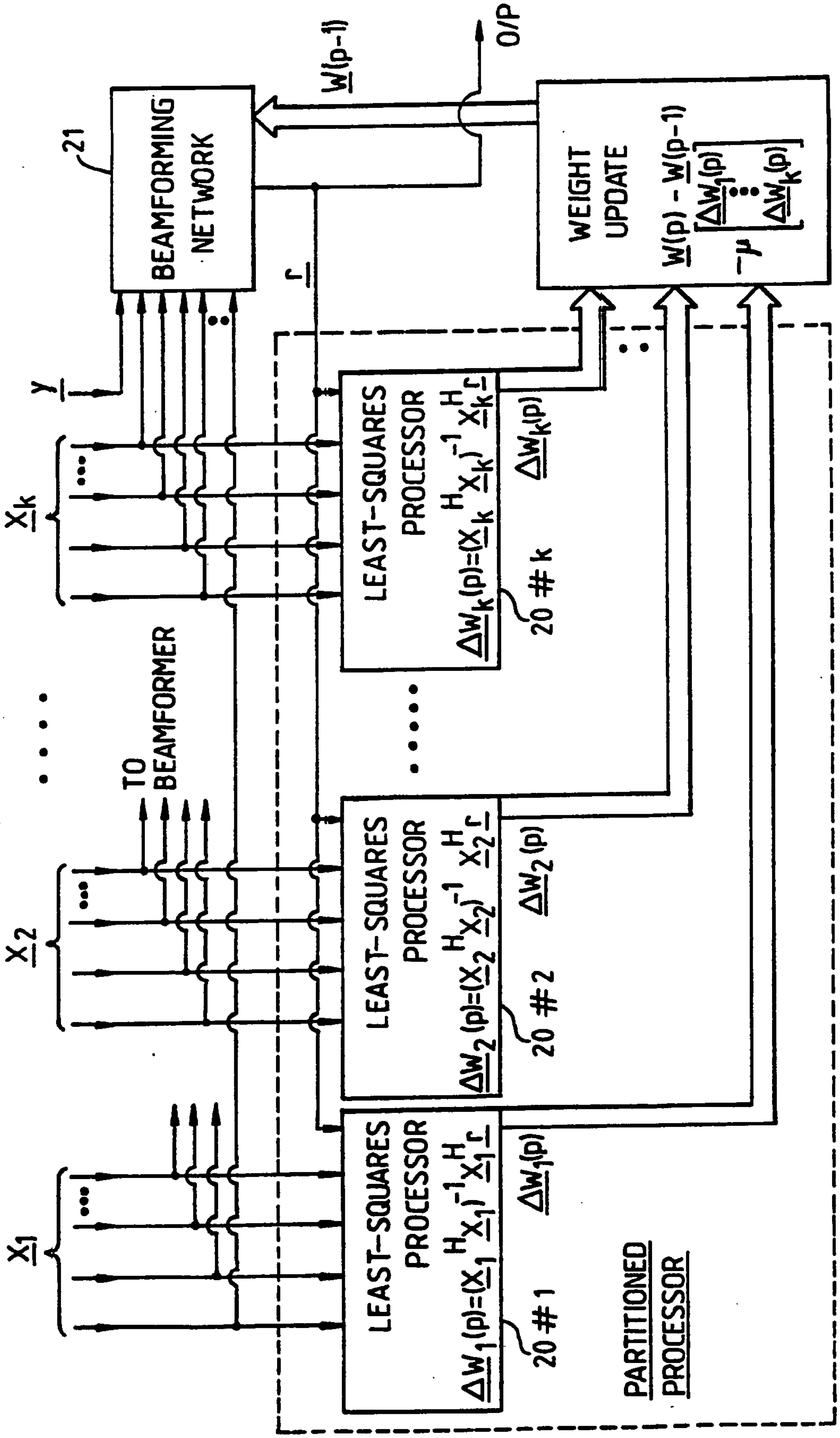


Y
X
BEAMFORMER
WEIGHTING
NETWORK
Σ
10
12
r = X W(p-1) + Y
W(p-1)
WEIGHT
UPDATE
W(p)= W(p-1)-
μ ΔW
BEAM PATTERN CONTROLLER
13
ΔW
A-D
A-D
A-D
LEAST-SQUARES
PROCESS
e.g.
QR
DECOMPOSITION
ΔW= (X^H X)^-1 X^H r
r
11
X

Fig.1.

Fig.2.



BEAMFORMING NETWORK
21
W(p-1)
O/P
WEIGHT UPDATE
W(p) - W(p-1)
-μ [ΔW1(p) ... ΔWk(p)]
r
y
Xk
X2
X1
TO BEAMFORMER
LEAST-SQUARES PROCESSOR
ΔWk(p)=(Xk^H Xk)^-1 Xk^H r
ΔWk(p)
20 #k
ΔW2(p)=(X2^H X2)^-1 X2^H r
ΔW2(p)
20 #2
ΔW1(p)=(X1^H X1)^-1 X1^H r
ΔW1(p)
20 #1
PARTITIONED PROCESSOR

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PROCESSOR FOR ADAPTIVE ARRAY.

This invention relates to a processor for an accelerated convergence adaptive antenna array.

The objective of an adaptive antenna is to select a set of amplitude and phase weights with which to combine the outputs from the elements in an array so as to produce a far-field pattern that, in some sense, optimizes the reception of a desired signal. The substantial improvements in system anti-jam performance offered by this form of array processing has meant that it is now becoming an essential requirement for many military radar, communications and navigation systems.

British patent application No. 2188782A discloses an adaptive antenna arrangement including a plurality of antenna elements in an array, a weighting network, one of the antenna elements providing a primary signal, the remaining elements providing auxiliary signal inputs to the weighting network, a beam pattern controller to which the auxiliary signals and beamformed output are applied, the controller being adapted to form amplitude and phase weights to be applied to the weighting network whereby the array beam pattern is continuously adjusted to contain nulls which track the bearings of unwanted received signals.

The controller derives an optimal gradient vector by a least-squares process, or an approximation to a least-square process, to update the weights which are then applied to the weighting network. A feedback signal being the beamformed output signal is applied to the controller to modify the weights to correct for weight non-linearity in the weighting network. A significant feature of the arrangement is the aspect concerning the introduction of the feedback signal into the least-squares processor algorithm which enables the system to correct for weight non-linearity and offsets and yet still retain a convergence performance which is comparable with an "open loop" or "direct solution" adaptive array process as described by J.S.Reed at al, 'Rapid Convergence Rate in Adaptive arrays", IEEE Trans., 1974, AES-10, pp 853-863 and C.R.Ward et al, "A Novel Algorithm and Architecture for Adaptive Digital Beamforming", IEEE Trans., AP-34, March 1986, No. 3, pp 338-346.

Figure 1 illustrates the key components of an accelerated convergence adaptive array which uses a least squares process (typified by the numerical method known as "QR decomposition") to calculate optimal weight correction vectors with which to update the weight solution applied by the weighting network.

In the arrangement shown in Figure 1 the signals received from all but one of the antenna elements $\underline{x}$ of the array at time t_i are applied to a weighting network 10 the output of which is combined in beamformer 12 with the signal from the remaining element $\underline{y}$. The signals from the element $\underline{x}$ are also applied to a least squares processor 11 in a beam pattern controller 13 wherein the optimal weight correction vector $\underline{\Delta W}$ = $(\underline{X}^H\underline{X})^{-1}\underline{X}^H\underline{r}$, where $\underline{X}^H$ is the Hermitian transpose of matrix $\underline{X}$ and $(\ )^{-1}$ implies the inverse of the matrix, is derived by the least squares process, or preferably by the QR decomposition process. This vector is then used to update the weights W (p-1) applied to the signals from elements x in the weighting network 10. The resultant weighted signals are summed and then combined with the signal from element y to form the output r = x W (p-1) + y of the beamformer 12. This output signal r is fed back to the processor 11 to allow for correction of weight non-linearity.

In British application 2188782A there is also disclosed a modification of the accelerated convergence adaptive antenna in which means are included for time multiplexing the signals applied to the processor 11 whereby the beam pattern controller performs the QR decomposition in a time shared mode, the signals being processed in a cyclic manner. This allows the number of inputs to the QR processor to be decreased, hence the complexity of the processor can be reduced.

According to the present invention there is provided an accelerated convergence adaptive antenna arrangement wherein the auxiliary signal inputs to the beam pattern controller are divided into groups, the controller being provided with an equivalent number of processors, each group of auxiliary signals being processed separately in conjunction with the beamformer outputby a respective processorthe operation of which is to compute a weight correction vector by a least squares process or an approximation thereof, all the groups being processed in parallel to form a set of weight correction vectors which are used to update the weight vector applied to the beam forming network to which all the auxiliary signals and primary channel signal are applied.

An embodiment of the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 depicts the key components of a known accelerated convergence adaptive antenna (already referred to), and

Figure 2 depicts the key components of an accelerated convergence adaptive antenna array with separate processors operating on groups of auxiliary signals.

In the arrangement shown in Figure 2 the auxiliary signals from the antenna elements are divided into groups of signals $\underline{x}_1$, $\underline{x}_2$ ...$\underline{x}_K$. Each group of auxiliary signals is fed to a respective processor 20#1, 20#2...20#k wherein a least squares or equivalent processing algorithm is performed on the group of signals. The separate processors derive weight correction vectors $\underline{\Delta W}_1(p)$, $\underline{\Delta W}_2(p)$,.....$\underline{\Delta W}_K(p)$,

where $\underline{\Delta W}_1(p) = (\underline{x}_1{}^H \underline{x}_1)^{-1}\underline{x}_1{}^H \underline{r}$ and so on.
This set of correction vectors is used to update the weight vectors ($\underline{W}$(p-1) applied to the beam forming network 21 to which all the auxiliary signals $\underline{x}_1$ - $\underline{x}_K$ are fed together with the primary signal $\underline{y}$. The output $\underline{r}$ of the beamformer is fed back to each of the processors to allow for correction of weight non-linearity. Partitioning of the off-line processing architecture to form separate smaller processors each handling only a group of auxiliary signal results in a significant reduction in circuit complexity compared with that of a single large processor handling all the auxiliary signals. The partitioned architecture also provides an improvement in convergence rate performance compared to a conventional steepest descent algorithm as typified by the Widrow LMS technique in B.Widrow et al, "A

Comparison of Adaptive Algorithms Based on the Methods of Steepest Descent and Random Search", IEEE Trans., 1976, AP-24, pp 615-637, and the time shared arrangement described in British patent application 2188782A.

CLAIMS.

1. An accelerated convergence adaptive antenna arrangement wherein the auxiliary signal inputs to the beam pattern controller are divided into groups, the controller being provided with an equivalent number of processors, each group of auxiliary signals being processed separately in conjunction with the beamformer output by a respective processorthe operation of which is to compute a weight correction vector by a least squares process or an approximation thereof, all the groups being processed in parallel to form a set of weight correction vectors which are used to update the weight vector applied to the beam forming network to which all the auxiliary signals and primary channel signal are applied.

2. An accelerated convergence adaptive antenna arrangement substantially as described with reference to Figure 2 of the accompanying drawings.

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